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IMPROVEMENT OF THERMAL CONDUCTIVITY OF P91 STEEL USING BORON NITRIDE COATING

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ABSTRACT

P91 material has been used in Power Plant. It is also called 9 Cr 1 Mo steel, based on its composition. The oxidation temperature limits are higher. This allows the power plant designers to engineer components, super heater coils, headers and steam piping, with less thickness. P91 steel contributes to a higher thermal fatigue life of almost ten times. This allows them to increase the operating temperature to a higher level, increasing the efficiency of the power plant. Boron nitride coating is used to improve the thermal conductivity of the P91 pipe. The present study deals with comparison of P91 steel pipe with Boron Nitride and without Boron Nitride, and the Thermal Strain are to be analyzed in Engineering Workshops.

KEYWORDS: P91, Thermal Conductivity, Boron Nitride & Thermal Strain

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Original Article

INTRODUCTION

[1] The P91 steel has solid solution strength, sub grain hardening and precipitation hardening. Its weldments are used for heat treatment and creep exposure conditions. The microstructure of P91 has long term aging and creep exposure conditions [2]. When treated up to 810°C at tempering state, almost all martensitic laths were decomposed into sub grains and microstructure of the invested steel [3]. Chromium molybdenum alloy steels are used in high temperature service centers. Supplementary analysis by energy dispersive x-ray spectroscopy was made at diverse regions. [4] Very High Temperature reactor (VHTR) is a reactor, internal of which makes the creep strength enhanced ferritic P91 Steel that has a candidate material for reactor pressure vessels. [5] Circumferential cracks are observed with increasing primary load and a very complex crack is observed with no actual primary load in thermal fatique tests. [6] It is considered that a thermal ratcheting in a cylinder, subjected to a moving axial temperature gradient with no primary stress applied. [7] Water immersion test had no trend of mass gain percentage with increasing amount of nano sized Boron Nitride inside the coating. [8] A high through plane thermal conductivity of 9 W/mK is obtained on h-BN loading. [10] Additives used are decreasing the effect of thermal diffusivity and conductivity of hBN/HDPE composites. [11] Other alternatives adopted are PPCM for increasing the thermal conductivity of paraffin and dispersing paraffin in thermal conductive materials which are metal particles. [12] Optical microscopic studies show that there is no gross porosity or cracks present at the interface. [13] The highest density which was found with best properties was obtained at 1600°C

MATERIALS USED

Boron Nitride Spray

Boron nitride is an aerogel made of highly porous BN. Figure 1 shows the Boron Nitride Spray. It typically consists of a mixture of deformed BN nanotubes. It can have a density as low as 0.6 mg/cm3 and a specific surface area as high as 1050 m2/g. BN aerogels are highly hydrophobic and can absorb up to 160 times their weight in oil. They are resistant to oxidation in air at temperatures up to 1200 °C.

Figure 1: Boron Nitride

P91 Steel Pipe

Grade T/P91 is a ferritic-martensitic (9 % chromium, 1 % molybdenum) steel micro-alloyed with vanadium and niobium. P91 material has been in used in Power Plant. It is also called 9 Cr 1 Mo steel based on its composition. It increases the efficiency of power plant. Grade T/P91 exhibits excellent elevated-temperature strength and creep behavior up to 580 °C - 600 °C.

KD2 Pro Analyzer

KD2 Pro analyzer uses the transient line heat source and replaceable sensors to measure thermal conductivity, resistivity, diffusivity and volumetric specific heat. Figure 2 shows the KD2 Pro Analyzer apparatus

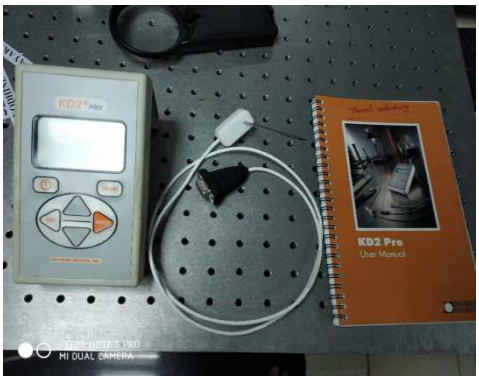

Figure 2: KD2 Pro Analyzer

THE PROCESS

At first, the idea of improving the thermal conductivity of any pipe was studied in some of the literatures that we have given. Then, we came to a conclusion to do the testing with P91 Steel pipe, which has a high melting point of 1650°C. It consists of 9 Cr 1 Mo Steel based its composition. This steel was very rare to find, as we searched in online and even in steel manufacturing companies. We didn't get the exact composition of steel. Then after a month, we ordered the

steel from Mumbai of the length of 1m and 3.5mm thickness. It took a week to reach our location. Then the search was for Boron nitride. We searched in various chemical centers in Chennai. As we are going to spray the Boron nitride on the steel surface, we didn't get the material in liquid form. The material was very hard to convert it from solid to liquid. So, this took us lot of time to search for the right type of boron nitride spray. Then at last we ordered boron nitride spray online, which consists of 100 ounces of liquid in it. But this spray, as it was under heavy demand, it took 2 months to get delivered. Then after, we received both the materials and we were ready for the testing processes and to experiment our idea to increase the thermal conductivity of the pipe. The P91 Steel bought is checked for its physical properties. It is found to have a stable thermal conductivity around 26 W/mK. The thermal conductivity of P91 Steel Pipe is tested using KD2 Pro Analysis. The objective of our project is to increase the thermal conductivity more, by using the Boron nitride coating. To take the test in a KD2 Pro analyzer, the length of the material should be 100mm and there should be a drilled whole with the depth of 100mm and with the thickness of 2.5mm. Now, this process of drilling nearly took us lots and lots of time in this project. The drilling process consists of drill bit with the thickness of 2.5mm, but it cannot be drilled up to 100mm. Practically, it's not possible as it's not under use. Then, we searched for the drill bit in many places. At last we ordered the drill bit with the exact dimensions from Bangalore in the month of January. Then after it got delivered, we lowered the size of our work piece and drilled it to the required size in the nearby Engineering workshop. Then heat treatment was done using the muffle furnace in our college premises. Heat was supplied at a maximum of 830°C and the time at which the work piece is heated for every 10°C was noted from 600°C to 830°C. The drill bit had a small error of 0.1mm. This was noticed after some days only. So, we were not able to place the material properly in the KD2 Pro Analysis needle. It was not going inside. This wasted us lot of time. Then again, we took the work piece to the Engineering workshop and spark cutting was again done inside the whole, to increase the diameter to about 0.15mm. Then we took the work piece to VIT University, where the KD2 Pro Analysis was done. The work piece got inserted inside the needle of the machine. But, we had another problem. The machine had and error and it was not in a condition to test our material. We got the wrong reading of thermal conductivity. Then we decided to test with the machine from any other Engineering centers. Hence, we approached a testing center in Coimbatore. We gave our material along with the Boron nitride spray. We tested first, the thermal conductivity of the steel without applying boron nitride; then again another test was done by applying Boron nitride. This testing was done in the KD2 pro analyzer machine and we found that there was increase in the thermal conductivity of the steel. We got the exact results after some days through mail. The readings where listed and the increase of the thermal conductivity was noted and was presented in a table, and also it was produced neatly in a graph to show the difference. Hence, we were able to increase the thermal conductivity of the P91 Steel with the help of Boron nitride coating sprayed on it.

RESULTS AND GRAPHS

Table 1: Comparison of Thermal Conductivity with and without Boron Nitride

Temperature Range	Uncoated Samples Thermal Conductivity (W/mk)	Coated Samples Thermal Conductivity (W/mk)
25	28	28.75
50	29	30.23
75	29.5	30.88
100	30.23	31.98
125	31	33.45
150	31.44	33.99

The Table 1 shows the difference in the thermal conductivity when the Boron Nitride is coated on it. The P91 steel was heated from room temperature to 50°C, 75°C, 100°C, 125°C, 150°C, respectively. Thermal conductivity of the pipe was tested before coating Boron Nitride on it, for the above temperatures. Then Boron nitride was coated on the outer surface of the work piece. Thermal conductivity using the KD2 Pro Analyzer was tested for those respective temperatures. The thermal conductivity shows increase when treated with boron nitride. So, boron nitride can be used to increase the thermal conductivity of P91 steel.

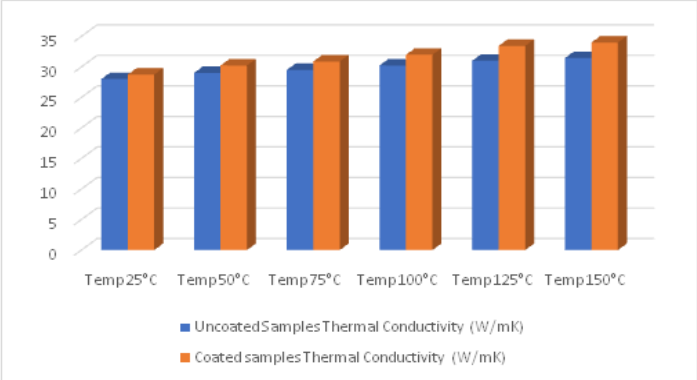

Figure 3: Comparison of Thermal Conductivity With& Without Boron Nitride Coating

Figure 3 show the comparison of increase in thermal conductivity. The blue column shows the thermal conductivity for different temperatures when boron nitride coating is not applied. Work piece is heated from room temperature up to 150°C. After applying boron nitride on the work piece, the thermal conductivity is increased which is indicated in the red column.

CONCLUSIONS

We used the P91 steel pipe and tried to increase its thermal conductivity with some type of chemicals. Then we found that, Boron Nitride has a high ability to increase the thermal conductivity on any metal. So, we gave a Boron Nitride coating on our work piece (P91 Steel). We found the thermal conductivity of P91 Steel using KD2 Pro Analysis test. The addition of boron nitride on the work piece increased its thermal conductivity. Hence, we found that the boron nitride Aerosol spray will increase the thermal conductivity of the metal or steel in which it is coated. It is applicable in extending the lifetime of the metals

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